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Optimization of Pertinent Variables for Threshing of Sesame Crop using a Test Rig

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ABSTRACT

Background: The traditional methods of threshing operations are most time consuming, energy intensive, labour intensive, drudgery prone and uneconomical. The development of mechanical sesame thresher has clearly an edge over conventional methods and reduces the drudgery of work to a great extent.

Methods: The pertinent variables that influence the development of sesame thresher were identified and levels of variables were selected. The interactive effect of selected levels of variables *viz*., peripheral velocity of the threshing cylinder (7.9, 11.0 and 14.1 ms^{-1}), concave clearance (10, 15 and 20 mm), type of threshing cylinder (wire loop, spike tooth and rasp bar) and moisture content of harvested sesame capsule 21.4, 16.8 and 15.1 per cent moisture content (d.b) was investigated on threshing efficiency, cleaning efficiency and per cent damage caused to the threshed sesame grains using an experimental sesame thresher test rig under laboratory condition.

Result: Threshing effectiveness of experimental sesame thresher was found to be affected significantly by moisture content of harvested sesame capsule followed by type of threshing cylinder, peripheral velocity of threshing cylinder and concave clearance. The combination level of 11.0 ms^{-1} peripheral velocity of threshing cylinder, 15 mm concave clearance, spike tooth type cylinder and 16.8 per cent (d.b) moisture content of harvested sesame capsule which yielded the maximum threshing efficiency of 99.0 per cent, maximum cleaning efficiency of 99.4 per cent and minimum per cent visible damage to threshed sesame grains of 0.79, is optimized for the sesame thresher.

Key words: Cleaning efficiency, Oil seeds, Sesame, Test rig, Threshing efficiency.

INTRODUCTION

In the conventional method, the stages involved in the process of threshing the harvested sesame crop stalk are as: (i) Curing for three days after harvest to remove the grains by initial shaking, (ii) Drying for one more day after curing (four days after harvest) to remove grains (matured) by subsequent shaking and (iii) Manual beating the crop stalks after five days to remove the remaining grains from the stalks. In order to achieve maximum threshing efficiency by minimizing the loss of grains and ensuring timeliness of threshing, three levels of moisture content of sesame capsule *viz*., moisture content after first day of harvest, moisture content after three days of harvest and moisture content after five days of harvest were selected for the investigation.

Existing practice of sesame threshing

The sesame crop stalks immediately after harvest are stacked one over the other in a circular heap with the stems pointing up and the grain portion pointing down as shown in Fig 1. The top portion of heap is covered with straw to increase the humidity and temperature of the heap. This curing process is continued for three days and due to initial shaking after that, as shown in Fig 2, about 25 per cent of the grains will fall off the stalks. After drying for one more day, subsequent shaking as shown in Fig 3 results in falling of all the matured grains. The grains are winnowed and dried in the open sun for three days. During this process, the grains are stirred once in 3 hours to obtain uniform drying. Finally, by manual beating the sesame stalks as shown in Fig 4, the remaining grains are removed from the stalks.

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MATERIALS AND METHODS

Selection of machine variables

The design, construction and experiments in sesame threshing test rig were conducted during 2018 at Agricultural Engineering College and Research Institute, Kumulur. The factors affecting the efficiency of threshing operation are feeding method, cylinder speed, concave-to-cylinder clearance and moisture content (Kepner *et al*., 1978). The performance of a thresher depends upon its size, cylinder speed, cylinder concave clearance, fan speed and the sieve shaker speed (Kaul and Egbo, 1985). The five parameters that influenced threshing efficiency and kernel damage, namely, cylinder peripheral speed, cylinder type, concave type, concave clearance and grain moisture content. The concave clearance and cylinder peripheral speed has significant effect on the threshing efficiency and grain damage for pulse threshers (Tandon *et al*., 1988). The important factors affecting the efficiency of the mechanical pod stripping element are speed of operation and condition of crop (Gol and Nada, 1991). The speed of threshing cylinder and moisture content had significant effect on chickpea threshing efficiency and damaged grain percentage (Khazaee, 2002). Increase in threshing efficiency was observed very slowly with increase of feed rate within all experimental range of moisture content, threshing sieve size and drum speed (Fulani *et al*., 2013). The important parameters which influence the threshing efficiency are mechanical damage, moisture content, threshing cylinder speed, feeding rate and concave clearance (Somachai Chuan-udom, 2012 and Naveen Kumar *et al*., 2013). Hence the variables selected for the investigation are furnished below:

i. Peripheral velocity of threshing cylinder (V).
ii. Concave clearance (C).
iii. Type of the threshing cylinder (D).
iv. Moisture content of sesame capsule (M).

Peripheral velocity of the threshing cylinder (V)

Commercial threshers developed for cereals operate at higher speeds and not suitable for threshing other crops. It damages the seeds leading to lower quality of seeds and poor germination. At higher cylinder speed the energy transfer to the threshing material by cylinder increased resulting higher grain damage. The percentage of grain loss decreased with decrease in feed rate levels and increased with increase in cylinder speed. The germination percentage was directly proportional to the concave clearance and inversely proportional to the cylinder tip speed (Sharma and Devnani, 1979). The peripheral velocity adopted for threshing mechanism varied from 300 to 900 rpm. But for crop stalks and capsule size similar to sesame, the optimized peripheral velocity of threshing mechanism arrived by researchers vary from 500 to 900 rpm (Sharma and Devnani, 1979). Hence three levels of peripheral velocity of threshing cylinder *viz*., 500, 700 and 900 rpm (7.9, 11.0 and 14.1 ms^{-1}) were selected for the investigation.

Concave clearance (C)

The seed separation from the stalks and passage of seed through the concave grate is a function of variables such as crop feed rate, threshing speed, concave length and cylinder diameter and concave clearance (Huynh *et al*., 1982). The radial distance between the concave and the outermost point of the threshing cylinder is called concave clearance. This clearance can be adjusted by either moving the cylinder or the concave up or down, some have adjustment for front and rear to move. In spike tooth thresher, the studs can be loosened or tightened to adjust the clearance. After the concave is properly adjusted, cylinder speed is then adjusted to achieve maximum threshing with the least crop damage. The concave clearance adopted for threshing mechanism varied from 5 to 40 mm. But for crop stalks and capsule size similar to sesame, the optimized concave clearance of threshing mechanism used by researchers vary from 10 to 25 mm (Sharma and Devnani, 1979). Hence three levels of concave clearance *viz*., 10, 15, 20, mm was selected for the investigation.

Type of threshing cylinder (D)

The types of threshing cylinder adopted for threshing mechanism are spike tooth, peg tooth, rasp bar, wire loop and hammer mill. The threshing cylinder used which is suitable to the sesame crop are taken. The type of threshing cylinder employed by the researchers are wire loop, spike tooth and rasp bar types. Hence three elements of wire loop, spike tooth and rasp bar type cylinders were selected for the investigation.

Moisture content (M) of sesame capsule

The properties of the crop that affect the thresher performance are crop variety, ear size, feed rate and cylinder speed. The properties of the crop that affect the thresher performance are crop variety, shape and size of seed, hardness of the seed, the moisture content of the seed and the density (Oni and Ali, 1986). The kernel breakage increased with increases in moisture content of the kernels (Alonge and Adegbulugbe, 2000). The level of moisture content are selected as 21.4 d.b., 16.8 d.b. and 15.1 d.b. High moisture content and low cylinder speed tend to reduce the percentage of damage seed, blown seed and seed loss respectively while low moisture content and high speed tends to increase the percentage of damage seed, blown seed and seed loss respectively. Moisture content state and impact on grain during threshing are paramount in determining crop mechanical damage (Allen and Watts, 1998 and Dauda, 2001). The grain damage increased with increasing peripheral speed and decreasing crop moisture content (Askari Asli-Ardeh *et al*., 2008). The higher threshing efficiency at lower moisture content during threshing of seed crops (Bansal and Lohan, 2009). The efficiency of the thresher was observed to vary with the moisture content of the grain (Omale *et al*., 2015).

Experimental sesame thresher test rig

An experimental sesame thresher test rig is constructed to investigate the influence of the selected levels of variables *viz*., peripheral velocity of threshing cylinder (V), concave clearance (C), type of threshing cylinder (D) and moisture content of harvested sesame crop capsules (M) under laboratory conditions on the threshing efficiency, cleaning efficiency and per cent damage caused to the threshed sesame grains.

The experimental sesame thresher test rig test rig consists of a main frame, threshing unit, blower and sieve assembly, feed chute, power transmission system and transport wheels as shown in Fig 5.

Constructional details of experimental sesame thresher test rig

Main frame

The main frame is a welded rectangular box structure of size 1140 × 910 × 1130 mm and is made by using 50 × 50 × 5 mm mild steel 'L' angle iron section. All the other functional components are attached to the main frame. The main frame supports the entire weight of the machine.

Feed chute

The feed chute is the component on which the harvested sesame crop is placed and fed into the threshing cylinder. It is made of 1.3 mm mild steel sheet. The feed chute is fixed at an inward inclination of 30° to facilitate the easy feeding of harvested sesame crops stalks into the threshing cylinder. The chute is of trapezoidal section of 600 mm length, 355 mm width and 255 mm height. The opening of the feed chute at the outer end and cylinder end is respectively 600 × 255 mm and 600 × 155 mm. The feeding chute was fixed at 1165 mm height from the ground level for safety and easy feeding.

Threshing unit

Threshing cylinder and concave makes the threshing unit. The diameter and length of hollow threshing cylinder is 300 and 600 mm respectively. It is made of 1.2 mm mild steel sheet metal. The threshing cylinder is common for all the three types of threshing elements *viz*., rasp bar, spike tooth and wire loop. The upper half of the threshing unit is enclosed with semicircular shield made of 2 mm mild steel sheet metal. The shaft made of 50 mm mild steel rod is fixed at the center of the threshing drum and the two ends of the shaft rest on plumber block bearings mounted on the main frame. For power transmission a 150 mm diameter 'V' pulley is fixed on the shaft at one end.

Wire loop threshing cylinder

In this type of cylinder, the threshing elements are in the form of wire loop. The wire loop cylinder consists of 8 numbers of bars made of 40 × 7 mm mild steel flat for 600 mm length. The bars are fixed on the periphery of the threshing drum at equidistant. The number of wire loops on each bar vary from 11 to 12 in alternate manner. The wire loop is made of mild steel round rod of 5 mm diameter and 80 mm long. The wire loops are welded on each bar at uniform spacing of 54 mm.

Spike tooth threshing cylinder

In this type of cylinder, the threshing elements are in the form of spike tooth. The spike tooth cylinder consists of 8 numbers of bars made of 40 × 7 mm mild steel flat for 600 mm length. The bars are fixed on the periphery of the threshing drum at equidistant. The number of spike tooth on each bar vary from 11 to 12 in alternate manner. Each spike tooth is made of mild steel flat of 25 × 10 mm for 80 mm long. The spike tooth is welded on each bar at uniform spacing of 54 mm.

Fig 1: Heaping of the harvested sesame stalks for curing.

Fig 2: Initial shaking of harvested sesame stalks after curing.

Fig 3: Shaking of sesame stalks after three days of curing and subsequent drying.

Fig 4: Manual beating of sesame stalks to separate the remaining grains from stalk.

Rasp bar threshing cylinder

In this type of cylinder, the threshing elements are in the form of rasp bars. It consists of four number of corrugated steel bars of 600 mm length mounted axially on the periphery of the cylinder at equal distance. The corrugations of rasp bar are cut on mild steel flat of 40 × 10 mm. The height of corrugations is 7 mm. The corrugations on the bars run opposite on adjacent bars as shown in the Fig 6.

Concave

The concave separates the grain from the crop and removes the grain from the straw. It is provided in the thresher to hold the fed crops inside the threshing chamber and allows only grain and small amount of chaff to pass through it. The threshing takes place only in this space. It is curved unit fitted below the threshing cylinder. Since the mean effective length of sesame stalk was 600 mm, the concave length was arrived as 600 mm. The mean width of sesame capsule is 5.65 m respectively and hence the mesh size of the concave was fixed as 50 × 5 mm so that the capsule will not pass through the concave mesh opening.

For this investigation, to maintain the uniform concave clearance, two types of concave are employed, one common for both wire loop and spike tooth cylinder and the other one for rasp bar cylinder.

The concave of wire loop and spike tooth cylinder is 50 × 5 mm mesh type and bent into an arc length of 600 mm. It is fixed below the threshing drum. The concave is made of 5 mm square rods welded to 30 × 7 mm mild steel flats at the two ends. The curvature (α) for spike tooth and wire loop cylinder concave is 120°. The schematics of concave arc curvature is shown in Fig 7.

The concave of rasp bar cylinder is 50 x 5 mesh type and bent into an arc length of 600 mm. It is fixed below the threshing drum. The concave is made of 5 mm square rods welded to 30 × 7 mm mild steel flats at the two ends. The curvature (α) for spike tooth and wire loop cylinder concave is 170° as shown in the Fig 8. The concave near the feeding end is hinged at both ends and connected to a slot with necessary supports to the main frame. This arrangement enables the concave clearance to be fixed at selected levels *viz*., 10, 15 and 20 mm for conducting the laboratory investigation.

Cleaning unit

The cleaning unit consists of the blower, sieve and the outlet tray.

Blower assembly

The blower is made of 1.6 mm mild steel sheet metal work. The blower housing was nautilus shaped with a major diameter of 200 mm, width of 340 mm and length 430 mm. The inner diameter for air inlet is 80 mm and the size of throat of the blower housing is 430 × 50 mm. The blower fan consists up of four paddle blades of 400 × 55 mm, made of 1.3 mm mild steel metal sheet. All the four paddles are fixed on 28 mm diameter blower shaft with bolts and nuts. The blower outlet is directed towards the sieves to blow out the chaff and dusts from grains. The two ends of the shaft rest on pillow block bearings mounted on the main frame. For power transmission a 150 mm diameter 'V' pulley is fixed on the shaft at one end.

Sieve assembly

The threshers are equipped with two sieves of perforated sheets having rectangular slots. The top sieve is provided so as not to pass the chaffs to the bottom sieve. The size of sieve hole for the top sieve is fixed as 20 mm mean which is lower than the value of sesame capsule size 20.37 mm so that the sesame capsules are retained on the top sieve. The top sieve is made up of 1.6 mm mild steel sheet metal of 520 × 790 mm with each slot size of 20 × 5 mm.

The bottom sieve screens the small sesame stalk chaffs and deliver the clean grain towards the collection tray. It is made of 1.6 mm mild steel sheet metal of 520 × 790 mm with rectangular slot hole of 35 × 3 mm. The size of sieve hole for the bottom sieve is fixed as 3.5 mm which is higher than the length of sesame grain of 3 mm so that the sesame capsules will pass through the bottom sieve to the grain collection tray. The lower sieve is placed 65 mm below the top sieve. The upper and lower sieves are placed in a rectangular tray of 790 × 520 mm made of 1.6 mm mild sheet metal. These sieves are oscillated or shaken with a crank attached to the trays. The crank is attached to a cam pulley having slot length of 30 mm in which the circular motion of the main shaft of 35 mm diameter is converted into oscillating motion of sieve. For power transmission a 200 mm diameter 'V' pulley is fixed on the shaft at one end.

Grain outlet tray

The grain outlet is a rectangular tray of 980 × 415 × 65 mm made of 1.6 mm thick mild sheet metal (lower frictional angle and coefficient of friction of sesame grains for metal surface) and fitted with bottom sieve at an inclination of 40° (more than the angle of repose of sesame grains 30° to facilitate easy flow of sesame grains.

Transport wheels

The thresher is provided with four wheels, two in the front and two in the rear portion for easy transportation. These wheels are made with 2.6 mm mild steel sheet metal rolled to circular wheels of 300 mm diameter and 50 width mm at the rear and 200 mm diameter and 40 mm width at the front. The wheels are attached to the axle which in turn is attached to a handle for moving the unit.

Prime mover

For the experimental sesame thresher test rig, a three phase one hp variable frequency drive of 1200-120 rpm, electric motor was used as the power source. The motor is mounted on one side of the top corner of the mainframe with necessary supports. The power is transmitted from the motor to the threshing cylinder shaft, blower shaft, sieve shaker shaft through a V-belt and pulley arrangement with a speed ratio of 1:1 as shown in the Fig 9. The specifications of experimental sesame thresher test rig are furnished in Table 1.

RESULTS AND DISCUSSION

All types of threshers are evaluated for their performance in terms of threshing efficiency, cleaning efficiency and per cent

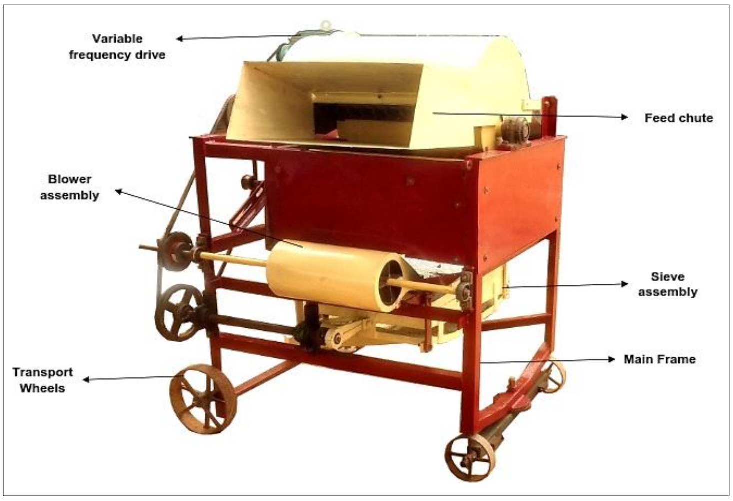

Fig 5: Experimental sesame thresher test rig.

Fig 6: Different types of threshing cylinder.

Table 1: Specifications of experimental sesame thresher test rig as per IS test code (IS: 6284-1985) for thresher.

Details	Values
Overall dimensions (L×B×W), mm	1140×910×1175
Type of thresher	Throw-in
Threshing unit	
Type of threshing cylinder	Wire loop/Spike tooth/Rasp bar
Diameter of the drum, mm	300
Length of the drum, mm	600
Concave clearance, mm	Adjustable in three steps (10, 15 and 20)
Power required	One hp
Cleaning unit	
Type of blower	Centrifugal type
No.of blades	4
Length of blade, mm	430
Width of blade, mm	50
Number of sieves	2
Feed chute	
Shape	Trapezoidal
Size at the feeding end, mm	600 × 255
Size at the cylinder end, mm	600 × 155
Power transmission	V-belt and pulley
Transport wheels	Four iron wheels

damage caused to the threshed grains (Tandon *et al*.,1988; Dauda, 2001; Wacker, 2003; Ajav and Adejumo, 2005; Emara, 2006; Sessiz *et al*., 2007; Simonyan, 2009; Alizadeh and Khodabakhshipour, 2010; Somposh Sudajan *et al*., 2005; Baldev Dogra *et al*., 2013; Hussen Abagisa *et al*., 2015; Ajayi *et al*., 2014 and Olaye *et al*., 2016). The performance and evaluational parameters selected are furnished below.

i. Threshing efficiency.
ii. Cleaning efficiency.
iii. Per cent damage caused to the threshed sesame grains.

A total number of 243 treatments were conducted with selected levels of variables *viz*., of peripheral velocity of cylinder (7.85, 10.99 and 14.13 ms^{-1}), concave clearance (10, 15 and 20 mm), types of threshing cylinder (wire loop, spike tooth and rasp bar) and moisture content of sesame capsule (21.4 d.b, 16.8 d.b and 15.1 d.b.) using experimental sesame thresher test rig. The moisture content of harvested sesame stalks with capsule after curing and drying was estimated and the values are used in the investigation. The feed rate of 8 kg min^{-1} was kept constant for all the treatments of the investigation. For all the treatments, the evolutional parameters *viz*., threshing efficiency, cleaning efficiency and per cent visible damage to sesame grain were computed. The experimental sesame thresher test rig was fitted with the wire loop cylinder and it was set to run at selected level of peripheral velocity of 7.85 ms^{-1}, concave clearance of 10 mm and moisture content of 21.4 per cent d.b and then it was similarly done for selected levels of variables as different combinations. The experimental sesame thresher test rig was run by three phase variable frequency drive electric motor for conducting trials. A bundle of 8 kg of sesame crop stalk was fed uniformly into the thresher during a period of 60 seconds for a feed rate of 480 kg h^{-1}. The threshed sesame stalks at the outlet and chaffs were collected and the weight was recorded. The clean grain received at grain outlet was collected and the weight was recorded. From the samples of weight of the grain collected at grain outlet, the number of sesame grains with visible damage was separated and the weight of the sesame grains with visible damage

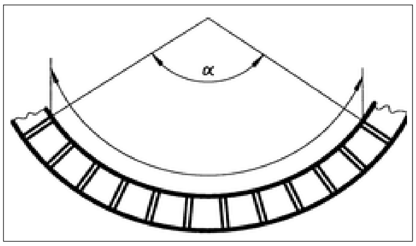

Fig 7: Concave arc (α) curvature.

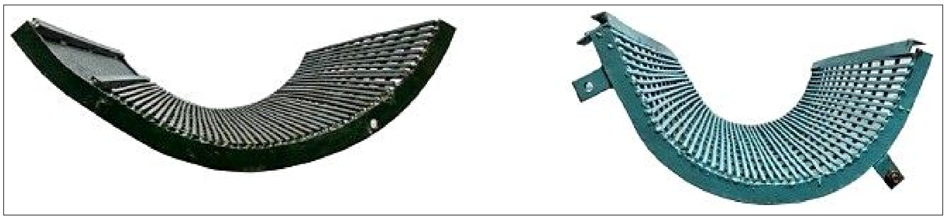

Fig 8: Concave curvature for spike tooth, wire loop type threshing cylinder (α= 120°) and rasp bar threshing cylinder (α= 170°).

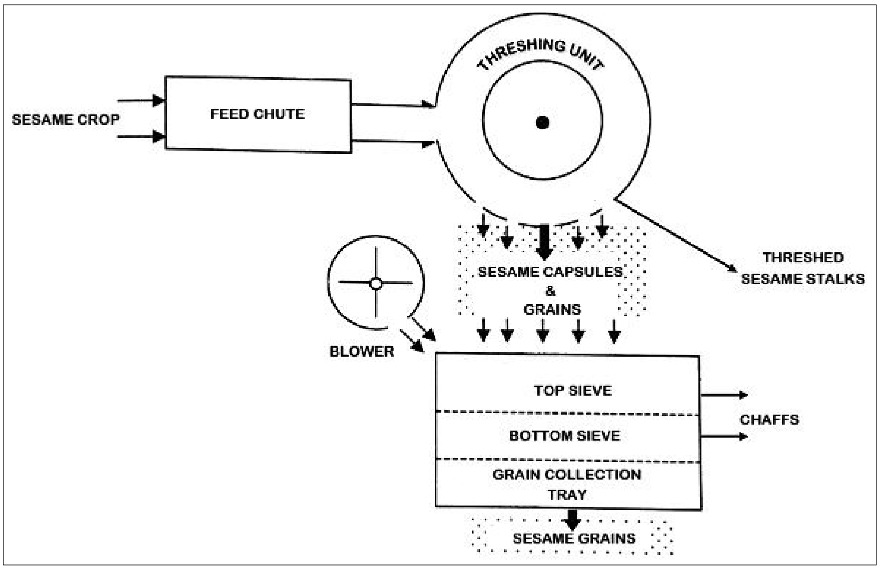

Fig 9: Sesame crop flow diagram.

was recorded. The same procedure was repeated for all the treatments.

A total number of 243 experiments were conducted using the experimental sesame thresher seeder test rig with selected levels of variables. The threshing efficiency, cleaning efficiency and per cent visible damage to sesame grains were computed for all the treatments of the investigation. Considering the maximum threshing efficiency and minimizing sesame grains loss by early threshing, the combination level of 11.0 ms^{-1} peripheral velocity of threshing cylinder, 15 mm concave clearance, spike tooth type cylinder and 16.8 per cent (d.b) moisture content of harvested sesame capsule which yielded the maximum threshing efficiency of 99.0 per cent, maximum cleaning efficiency of 99.4 per cent and minimum per cent visible damage to threshed sesame grains of 0.79, was optimized for the sesame thresher.

CONCLUSION

The optimization of the selected levels of variables for achieving best performance of experimental sesame thresher in terms of maximum threshing efficiency, maximum cleaning efficiency and minimum per cent visible damage to threshed sesame grains was studied. The combination level of 11.0 ms^{-1} peripheral velocity of threshing cylinder, 15 mm concave clearance, spike tooth type cylinder and 16.8 per cent (d.b) moisture content of harvested sesame capsule which yielded the maximum threshing efficiency of 99.0 percent, maximum cleaning efficiency of 99.4 per cent and minimum per cent visible damage to threshed sesame grains of 0.79, was optimized for the sesame thresher.

Conflict of interest

The authors declare no conflict of interest.

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